Evaluation of growth, yield, quality and physiological parameters of eleven Australian bread wheat (Triticum aestivum L.) cultivars grown under the ecological condition of Diyarbakir, Turkey

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Abstract

Wheat cultivars generally show significant differences for grain yield, quality and physiological parameters under different environmental conditions. Thus it is crucial to assess the performance of bread wheat genotypes collected from different origins for domestication for a specific ecological conditions and also to develop high yield as well as stress tolerant cultivars. In the context, the study was carried out under the ecological condition of Diyarbakir in Turkey during 2014-2015 growing season. In the present research, three Turkish origin bread wheat cultivars such as 'Pehlivyan', 'Ceyhan 99' and 'Serı 2013' and eleven bread wheat of Australian origin such as 'LPB 08-1799', 'Eagle Rock', 'Magenta', 'Emu Rock', 'Wyalkatchem', 'Young', 'Calingiri', 'Yitpi', 'Corack', 'Envoy' and 'Mace' were used as experimental plant material. Data on grain yield, grain hardness, plant height, test weight, thousand kernel weight, wet gluten, protein content, zeleny sedimentation, starch content, normalized differences vegetative index, SPAD, leaf area index and canopy temperature were investigated in the study. After evaluation, it was found that all recorded traits of fourteen wheat bread cultivars were changed according to cultivars under the ecological conditions of Diyarbakir-Turkey. However, genotypes which were Australian origin performed the best than Turkish origin. Among the genotypes, the maximum values for grain yield, quality and physiological parameters were recorded for cultivar, 'Mace' (for grain yield) and 'Young' (for quality traits). Therefore, cultivars which were Australian origin can be grown and may be used in the breeding programs to develop wheat cultivars to cultivate under the Diyarbakir ecological conditions of Turkey.

Keywords: Canopy temperature, Leaf area index, NDVI, Protein content

Introduction

Bread wheat (Triticum aestivum L.) plays a significant role in terms of human nutrition (Hossain et al., 2018). It serves as a staple food for 40 percent of the world’s population (Bockus et al., 2010). Wheat is consumed in different forms which includes; leavened breads and rolls, flat breads, porridge, biscuits, cakes, pasta and noodles (Shewry, 2009). It serves as a source of more 20% of the food calories (Bockus et al., 2010), protein, essential amino acids, minerals, vitamins and dietary fiber to the world's diet than any other food crops (Wijngaard and Arendt 2006; Shewry, 2009; Šramková et al., 2009; Kumar et al., 2011; Yıldırım et al., 2018) and also provides about 55 percent of the carbohydrates (Breiman and Graur, 1995) globally.

In Turkey, wheat contributes more than half of the calories and protein in the diet. Although, Turkey is the tenth biggest wheat producer in the world with annual production is around 21.5 million tons from a total wheat production area of 7.66 million ha in 2017. The average yield of wheat in Turkey is 2.8 tons ha⁻¹ (FAOSTAT, 2017). While its demand is increasing day by day to meet the food demand of the rapidly growing population. Therefore, it should be a continuous process to develop wheat varieties which are suitable to grow under the diverse environmental condition of Turkey. Although wheat has ability to grow multiple environmental conditions across the globe according their species, types as well as adaptability. Wheat plant generally shows differences in growth, grain yield, and quality traits as a result of variation of physiological and biochemical process of the plants under different environmental conditions. Some genotypes adapt easily to changing environment, while others are insufficient to adapt to changing conditions. Therefore, it is important to examine the wheat genotypes developed in different regions in terms of grain yield, quality and physiological parameters under diverse ecological conditions. The purpose of this study was to evaluate of the grain yield, quality and physiological parameters of some bread wheat cultivars which were originated from Australia and Turkey.


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Material and Methods

Plant material, growing conditions and design of field experiment

A field experiment was carried out during November to June, 2014-2015 at the Research Area of the Faculty of Agriculture, Dicle University, Turkey (latitude 37° 53' 21.50" N, longitude 40° 16' 34. 79" E and 670 m above sea level). In the study, three Turkish origin bread wheat cultivars (i.e. 'Pehlivan', Ceyhan 99, 'Seri 2013') and eleven Australian origin bread wheat (i.e. 'LPB 08-1799', 'Eagle Rock', 'Magenta', 'Emu Rock', 'Wyalkatchem', 'Young', 'Calingiri', 'Yitpi', 'Corack', 'Envoy' and 'Mace') were used as plant material. Monthly mean temperatures and precipitation are showed in Figure 1.

The study was established randomized complete block design with four replications. All the cultivars were grown in 4 m long 6 rows with a 20 cm row spacing. The plant was fertilized with 60 kg N and P ha⁻¹ (20:20:0 NPK) at sowing and 60 kg N ha⁻¹ (33 % ammonium nitrate) at tillering stage. The plants were harvested at full maturity by Hege-125 trial harvester machine in June.

Data collection and their procedure

Grain yield: Plot weight was calculated in kg plot⁻¹ and then converted to kg ha⁻¹

1000-kernel weight (TKW): In order to determine TKW, four hundred grains was counted with seed counter, which were then weighed (g) and the result multiplied by 2.5.

Plant height: Plant height was measured on ten randomly selected from the base of plant to the tip of the spike, by using a measuring tape.

Chlorophyll content (SPAD): Chlorophyll content is an indication for stay green or leaf senescence in agricultural research projects (Kizilgeci, 2019). Statistically significant differences were shown among bread wheat genotypes for SPAD. The results of this study showed that the chlorophyll content in all genotypes were varied significantly. The highest SPAD value (47.38) was obtained from 'Envoy'. Meanwhile, the lowest (39.85) was recorded from 'Emu Rock' (Figure 2 & Table 1). Chlorophyll content could be used as indicator to determine the performance of photosynthetic rate and reflect photosynthetic potential and primary production (Anjum et al., 2011). Reynolds and Trethowan (2007) reported that chlorophyll content or stay-green was correlated with the transpiration efficiency, which affects to the enhancement of water use efficiency under drought stress conditions. Grain yield had a significant positive relationship with leaf area and leaf chlorophyll content, and the correlation between leaf area and leaf chlorophyll content was also positive. Furthermore, the chlorophyll content can simultaneously increase grain yield, and plants with large leaves and grate chlorophyll content can also produce higher grain yield (Yeganehpoor et al., 2016).

Canopy temperature (CT): Canopy temperature is determined using an infrared thermometer (Rothenbenger) at heading stage. Data was recorded on clear sunny and calm days between 11:30 AM and 12:30 PM on plots with fully closed canopies. The sensor was held 1 m above the canopy at an angle of 30° to the horizontal. Assessments were made three times and the readings were averaged.

Leaf area index (LAI): This parameter was measured at heading stage by using LAI-2000 (LI-COR, Lincoln, NE).

Normalized differences vegetative index (NDVI): NDVI was measured using the Trimble GreenSeeker handheld crop sensor. Measurements were taken on sunny and cloudless day by passing the sensor over the plots at a height of about 40–50 cm above the canopy.

Statistical analysis: The obtained data were computed for proper statistical analysis according to SAS Program (1998). The LSD at 5% level of significance was used to differentiate between means.
The highest CT was recorded in 'Carack' (22.75 °C) and the lowest in 'Calingiri' (20.48 °C). The means of bread wheat varieties was found 21.87 °C (Figure 2 & Table 1). A lower canopy temperature has been linked to improved yield under heat stress (Reynolds et al., 2007; Bahar et al., 2011; Pinto and Reynolds, 2015; Deery et al., 2016; Öztürk and Aydin, 2017). Presumably genotypes with cooler canopies have the ability to extract more soil water (Reynolds et al., 2007). Lower canopy temperature has been previously linked to higher transpiration rates and therefore improved carbon capture and allocation efficiency and ultimately higher yields (Pinto et al., 2010; Cossani and Reynolds, 2015).

Normalized difference vegetation index (NDVI)

Spectral reflectance indices are important tools for evaluating photosynthetic traits. NDVI is one of the maximum broadly utilized vegetation indices as an indicator of canopy green area and it is associated with grain yield as well (Tanriverdi, 2003; Reynolds et al., 2007a; Kizilgeci et al., 2018). The differences among the bread wheat varieties were statistically significant for NDVI. The maximum NDVI value (0.772) was recorded in 'Pehlivan' and the minimum NDVI value (0.638) was recorded in 'Wyalkatchem' (Figure 2 & Table 1). The average NDVI of bread wheat varieties was 0.704. Crusioli et al., (2016) reported that NDVI estimates are affected by many factors, such as measuring stage, sensors and environment. Spectral reflectance NDVI is associated with yield and can be used to estimate stay-green (Lopes and Reynolds, 2012; Magney et al., 2016; Pinto et al., 2016; Rebetzke et al., 2016).

Plant height and leaf area index (LAI)

Plant height is a significant agronomic feature in bread wheat because of its closely associated with lodging. Plant height is also controlled by growing environment and also many genes. In the present study plant height was varied significantly for all genotypes under the ecological condition of Diyarbakir, Turkey. Among the genotypes, the maximum plant height was recorded in 'Pehlivani' (91.75 cm), while the minimum was recorded in 'LPB 08-1799' (55.00 cm). Turkish origin cultivars were taller than the Australian cultivars. Aykut et al., (2005) reported in a recent study that optimum plant height of wheat varieties have varied significantly from 70 to 100 cm, due to the genetic makeup of the specific varieties and also their interaction with growing environmental conditions.

Considering on the leaf area index of fourteen wheat genotypes, significant (p≤0.01) differences were found among cultivars. The highest LAI (3.83) was recorded from 'Magenta', while the minimum (2.78) was recorded from 'Seri 2013' (Figure 3 & Table 1).

Protein, starch and wet gluten content

The protein content is an inherent trait that can be influenced significantly by cultural practices, nitrogen practices and environmental factors. The differences among the bread wheat cultivars were statistically significant for protein content. The protein content varied between 14.36% ('Calingiri') and 16.48% ('Seri 2013') with an average of 15.41%. Previous bread wheat related researches reported the significant differences for protein content among genotypes which supports our results. Amanlıyev and İşankuliyev (2005) reported that the protein ratio of bread wheat at international standards is accepted as 12.5% (Figure 4 & Table 1).

Starch is also major constituent of the wheat grain. a significant difference was observed among cultivars. The maximum starch content (65.86%) was recorded in 'Calingiri' while, the minimum starch content (62.99%) was recorded in 'Magenta' (Figure 4).

While wet gluten is the main factor in determining the quality of bread in bread wheat, it constitutes almost 80 percent of the total protein in grain. The data related to wet gluten content for all observed cultivars were given in Table 1. In the study, wet gluten of all genotypes was varied significantly. The value of wet gluten was the highest at 'Seri 2013' (29.37) and the lowest wet gluten was recorded in 'Calingiri' (24.82) (Figure 4 & Table 1).

Zeleny Sedimentation and grain hardness

Zeleny Sedimentation value is an important feature that gives information about gluten quality of wheat flour (Ozen and Akman 2015). In the present study, Zeleny Sedimentation value for all genotypes were varied significantly under the ecological condition of Diyarbakir, Turkey. The zeleny sedimentation value of cultivars ranged from 43.01 ml ('Ceyhan 99') to 50.92 ml (Seri 82 and 'Magenta') (Figure 5 & Table 1).

Figure 2. Chlorophyll content (SPAD), Canopy temperature (CT) and normalized difference vegetation index (NDVI) of bread wheat cultivars under the ecological condition of Diyarbakir in Turkey during the wheat growing season of 2014-15.
Figure 3. Plant height and leaf area index (LAI) of fourteen bread wheat cultivars under the ecological condition of Diyarbakir in Turkey during the wheat growing season of 2014-15.

Figure 4. Protein, starch and wet gluten (%) content of fourteen bread wheat cultivars under the ecological condition of Diyarbakir in Turkey during the wheat growing season of 2014-15.

Figure 5. Zeleny sedimentation and grain hardness of fourteen bread wheat cultivars under the ecological condition of Diyarbakir in Turkey during the wheat growing season of 2014-15.
Grain hardness is one of the most important traits that determine the end-use quality of wheat and its technological utilization. Usually wheats called soft and hard bread wheat. Flour yields of hard wheat are higher than soft wheat. Significant differences were showed among the cultivars for grain hardness. The highest grain hardness was obtained from 'Pehlivan' (115.23), while the lowest grain hardness obtained from 'Calingiri' (89.58). The grain hardness values indicate the softness as close to 100. Aydoğan and Soylu (2016) stated that grain hardness is a genetic factor and is not affected by environmental conditions.

**Test weight and 1000-kernel weight**

Test weight is one of the factors the most important effect on the quality of wheat. Test weight was statistically significantly differed between cultivars. The highest test weight value in this study was found in genotype 'LPB 08-1799' (86.33 kg hl⁻¹). While the lowest test weight value was determined in 'Calingiri' (80.01 kg hl⁻¹) (Figure 6 & Table 1). Significant differences (p≤0.01) in the mean of 1000-kernel weight were found among bread wheat cultivars (Figure 6). Thousand kernel weight ranged from 25.49g ('Wyalkatchem') to 37.51g ('Pehlivan'). In terms of this trait, it was showed that varieties of Turkish origin have above average values.

**Grain yield**

The grain yield is considered a major parameter for screening wheat genotypes in breeding programs (Forgone, 2009). Grain yield in bread wheat is a complex character with several components, including genetic and environmental conditions. In terms of grain yield, differences among cultivars were found significant. The maximum grain yield was obtained from genotype 'Wyalkatchem' with 37.51g (‘Pehlivan’). In terms of this trait, it was showed that varieties of Turkish origin have above average values.

### Table 1. Mean data of investigated traits for bread wheat cultivars

<table>
<thead>
<tr>
<th>cultivar</th>
<th>NDVI</th>
<th>CT (°C)</th>
<th>SPAD</th>
<th>LAI</th>
<th>PH (cm)</th>
<th>PC (%)</th>
<th>SC (%)</th>
<th>WC (%)</th>
<th>ZS (ml)</th>
<th>Hardness</th>
<th>TW (kg ha⁻¹)</th>
<th>TKW (g)</th>
<th>Grain Yield (kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pehlivan</td>
<td>0.772a</td>
<td>21.60c</td>
<td>42.75c</td>
<td>3.20a</td>
<td>91.75a</td>
<td>15.85a</td>
<td>64.42a</td>
<td>28.8a</td>
<td>49.67a</td>
<td>115.23a</td>
<td>84.40abc</td>
<td>37.51a</td>
<td>4304.9h-e</td>
</tr>
<tr>
<td>Ceyhan 99</td>
<td>0.705a</td>
<td>21.55d</td>
<td>40.20ef</td>
<td>3.55a</td>
<td>82.59bc</td>
<td>14.47g</td>
<td>65.28b</td>
<td>26.85e</td>
<td>43.01e</td>
<td>107.90b</td>
<td>83.89bc</td>
<td>31.18ede</td>
<td>4484.0a-d</td>
</tr>
<tr>
<td>Seri 2013</td>
<td>0.688bcd</td>
<td>21.80bc</td>
<td>41.35def</td>
<td>2.78d</td>
<td>75.59bc</td>
<td>16.48a</td>
<td>63.36d</td>
<td>29.37a</td>
<td>50.92a</td>
<td>107.93b</td>
<td>64.78abc</td>
<td>33.60f</td>
<td>3859.0c-g</td>
</tr>
<tr>
<td>Lpb 08-1799</td>
<td>0.688bcd</td>
<td>22.27abc</td>
<td>44.65f</td>
<td>3.30a</td>
<td>55.50e</td>
<td>14.77f</td>
<td>65.34e</td>
<td>25.35d</td>
<td>50.8la</td>
<td>103.9e</td>
<td>86.35c</td>
<td>32.32e</td>
<td>4097.9ce</td>
</tr>
<tr>
<td>Eagle Rock</td>
<td>0.713a</td>
<td>22.14d</td>
<td>43.35e</td>
<td>3.18a</td>
<td>69.25d</td>
<td>15.63a</td>
<td>63.74d</td>
<td>25.98a</td>
<td>49.84a</td>
<td>97.27f</td>
<td>84.13abc</td>
<td>28.08fg</td>
<td>3702.11e</td>
</tr>
<tr>
<td>Magenta</td>
<td>0.700abc</td>
<td>21.83bc</td>
<td>43.65ef</td>
<td>3.83a</td>
<td>75.75bc</td>
<td>15.85a</td>
<td>62.94a</td>
<td>27.51b</td>
<td>50.92a</td>
<td>106.60b</td>
<td>84.13abc</td>
<td>30.14ecd</td>
<td>3854.9c-g</td>
</tr>
<tr>
<td>Enmi Rock</td>
<td>0.648cd</td>
<td>21.60a</td>
<td>39.85f</td>
<td>3.00b</td>
<td>73.25bc</td>
<td>15.30f</td>
<td>64.96d</td>
<td>27.65b</td>
<td>47.01c</td>
<td>95.97f</td>
<td>83.77bc</td>
<td>33.48b</td>
<td>3716.0d-g</td>
</tr>
<tr>
<td>Wyalkatchem</td>
<td>0.631a</td>
<td>21.85bd</td>
<td>41.33f</td>
<td>3.53a</td>
<td>59.75f</td>
<td>15.68d</td>
<td>64.55d</td>
<td>27.87a</td>
<td>49.82a</td>
<td>96.04f</td>
<td>83.74bc</td>
<td>25.49gh</td>
<td>2973.8h</td>
</tr>
<tr>
<td>Young</td>
<td>0.701abc</td>
<td>22.66a</td>
<td>43.13e</td>
<td>3.45b</td>
<td>70.00cd</td>
<td>16.19b</td>
<td>64.62d</td>
<td>26.25c</td>
<td>50.02a</td>
<td>101.62d</td>
<td>84.50abc</td>
<td>29.46f</td>
<td>3551.1f-g</td>
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<tr>
<td>Calingiri</td>
<td>0.698a</td>
<td>20.48d</td>
<td>40.43f</td>
<td>3.78a</td>
<td>72.50cd</td>
<td>14.36g</td>
<td>65.86a</td>
<td>24.82e</td>
<td>47.49cd</td>
<td>89.58g</td>
<td>80.01d</td>
<td>27.16gh</td>
<td>3238.9gh</td>
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<td>Yüpi</td>
<td>0.748ab</td>
<td>21.78c</td>
<td>44.85abc</td>
<td>3.63a</td>
<td>86.59b</td>
<td>15.22g</td>
<td>64.36d</td>
<td>27.26bc</td>
<td>50.24a</td>
<td>102.9c</td>
<td>83.66bc</td>
<td>33.63bc</td>
<td>4554.9abc</td>
</tr>
<tr>
<td>Corak</td>
<td>0.723abc</td>
<td>22.75a</td>
<td>44.63ad</td>
<td>3.80d</td>
<td>69.50cd</td>
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<td>Enviy</td>
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<td>3.58b</td>
<td>75.25bc</td>
<td>16.06abc</td>
<td>64.28d</td>
<td>28.32ab</td>
<td>50.41a</td>
<td>99.39d</td>
<td>85.09bc</td>
<td>32.39c</td>
<td>5038.5ab</td>
</tr>
<tr>
<td>Mace</td>
<td>0.734abc</td>
<td>21.91abc</td>
<td>42.98f</td>
<td>3.70a</td>
<td>74.55bc</td>
<td>15.15c</td>
<td>65.56a</td>
<td>27.16cd</td>
<td>49.52a</td>
<td>102.76c</td>
<td>82.52c</td>
<td>31.99bcd</td>
<td>5204.2a</td>
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<tr>
<td>Mean</td>
<td>0.704</td>
<td>21.87d</td>
<td>43.11</td>
<td>3.38</td>
<td>73.62</td>
<td>15.41</td>
<td>64.52</td>
<td>27.29a</td>
<td>48.91a</td>
<td>101.73a</td>
<td>83.93c</td>
<td>31.14a</td>
<td>4036.2</td>
</tr>
</tbody>
</table>

LSD (5%) 0.07** 0.94** 3.45** 0.65** 2.78** 0.95** 1.39** 2.10** 3.21** 2.41** 2.38** 1.90** 7.33**

**CV (%) 2.87 5.04 5.60 11.6 13.12 14.11 4.48 4.35 4.51 5.38 4.59 1.67 1.96**

* **Significant at 0.01**, **Significant at 0.05**, **Significant at 0.10** respectively. NDVI: Normalized differences vegetation index, CT: Canopy temperature, LAI: Leaf area index, PH: Plant height, PC: Protein content, SC: Scurch content, WC: Wt gain, ZS: Zeryn Sedimentation, TW: Test weight TKW: Thousand kernel weight.

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**Figure 6.** Test weight and 1000-kernel weight of fourteen bread wheat cultivars under the ecological condition of Diyarbakır in Turkey during the wheat growing season of 2014-15.
Conclusion

From the results and discussion of the study, it was found that grain yield, grain hardness, test weight, thousand kernel weight, plant height, wet gluten, protein content, zeleny sedimentation, starch content, NDVI, SPAD, LAI and canopy temperature of fourteen wheat bread genotypes were changed according to cultivars under the ecological conditions of Diyarbakir-Turkey. However, genotypes which were from Australian origin performed the best than Turkish origin. Among the genotypes, the maximum values for grain yield, quality and physiological parameters was recorded for genotype, 'Mace' (for grain yield) and 'Young' (for quality traits). Therefore, cultivars which were Australian origin can be grown and also may be used in the breeding programs for these valuable traits, under the Diyarbakir ecological conditions of Turkey.

Conflict of interest

Authors declared no conflict of interest

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